3D Additive Construction with Regolith for Surface Systems

Completed Technology Project (2013 - 2014)

Project Introduction

Planetary surface exploration on Asteroids, the Moon, Mars and Martian Moons will require the stabilization of loose, fine, dusty regolith to avoid the effects of vertical lander rocket plume impingement, to keep abrasive and harmful dust from getting lofted and for dust free operations. In addition, the same regolith stabilization process can be used for 3 Dimensional (3D) printing, additive construction techniques by repeating the 2D stabilization in many vertical layers. This will allow in-situ construction with regolith so that materials will not have to be transported from Earth. The goal is to prove the feasibility of 3D printing additive construction using planetary regolith and show structural integrity and practical applications in space exploration.

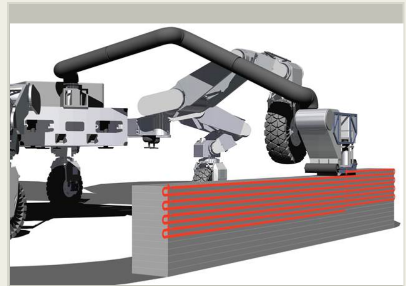
Recent work in the NASA Kennedy Space Center (KSC) Surface Systems Office (NE-S) Swamp Works and at the University of Southern California (USC) under two NASA Innovative Advanced Concept (NIAC) awards have shown promising results with regolith (crushed basalt rock) materials for in-situ heat shields, bricks, landing/launch pads, berms, roads, and other structures that could be fabricated using regolith that is sintered or mixed with a polymer binder.

These results indicate that the unique properties of granular planetary regolith are well suited for use as a construction material with high insulation values, low densities and good manipulation characteristics. Examples of regolith manipulation processes are solar heat sintering, microwave sintering, laser sintering, polymer binders, compaction, regolith paste extrusion and waterless concrete forming .

Methods of transferring regolith to a “3D Print Head” mounted on a robotic arm will be developed to investigate the feasibility of adhering the regolith particles together in successive 2D layers to achieve a 3D printing additive manufacturing proof of concept process with net shape characteristics of useful structures such as blast walls, landing pads, habitats, bricks, roads, antenna towers, heat shields and even propellant tanks. This will result in high mass savings as local in-situ regolith is without transporting material and equipment from Earth. Power consumption per product kilogram is determined for each transfer method.

Anticipated Benefits

3D Additive Fabrication is already planned to be demonstrated on the International Space Station (ISS). Polymer parts will be printed on ISS by Made in Space inc. This will prove the feasibility of "Massless Exploration" where parts can be made on the ISS with zero mass transported from Earth. The European Space Agency also plans to 3D print parts on ISS but made from a metallic powder feedstock. The possibilities and benefits are tremendous, so these initial steps are important to learn how to deal with the unique space environment especially micro-gravity.



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Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Lead Center / Facility:

Kennedy Space Center (KSC)

Responsible Program:

Center Innovation Fund: KSC CIF

Future feedstocks will include raw planetary regolith and feedstocks derived from the regolith such as aluminum, iron, titanium, platinum and magnesium. The lessons learned from the ISS efforts will be rolled into this technology development effort and vice versa.

The logistics required to set up a human outpost on another planetary surface are vast and prohibitively expensive. Space transportation costs are high, so the corresponding value of In-Situ Resource Utilization (ISRU) to make structures and spare parts using local materials is also high.

By developing new technologies to transport, position, emplace, bind and from a net shape with regolith, parts and structures can be built on Asteroids, the Moon, Mars and other moons so that a robust logistics space mission architecture will result which means higher reliability and safety.

3D printing is a game changer due to it’s efficiency and digital manufacturing methods which allows electronic computer files to be uploaded from Earth to a space destination and then structures and parts can be constructed or fabricated using local resources.

In addition, terrestrial spinoffs are also possible. The state of Hawaii has expressed interest in using this sustainable technology to build structures and roads using locally available in-situ volcanic lava basalt as a spin-off technology to build Hawaiian civil infrastructure such as sidewalks, roads, bridges, support structures and housing. By avoiding the importation of raw materials such as asphalt, Portland cement, pavers and bricks, the state of Hawaii will gain economically and reduce its dependence on good imported from the mainland. Raw basalt materials from the volcanic Hawaiian islands could be exported world wide, making Hawaii a net exporter of construction materials.

Currently houses cost hundreds of thousands of dollars to construct. By using 3D additive construction, it will be possible to reduce the construction cost of the primary structure by a factor of ten. Affordable housing will result in an increased standard of living for billions of people worldwide. Rapid deployment of 3D Additive Construction robots will make it possible to quickly and efficiently build disaster relief housing using locally available granular materials such as sand or crushed rock.

Project Management

Program Director:

Michael R Lapointe

Program Manager:

Barbara L Brown

Project Manager:

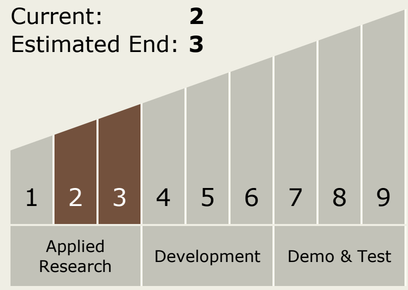
Robert P Mueller

Principal Investigator:

Robert P Mueller

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **3**

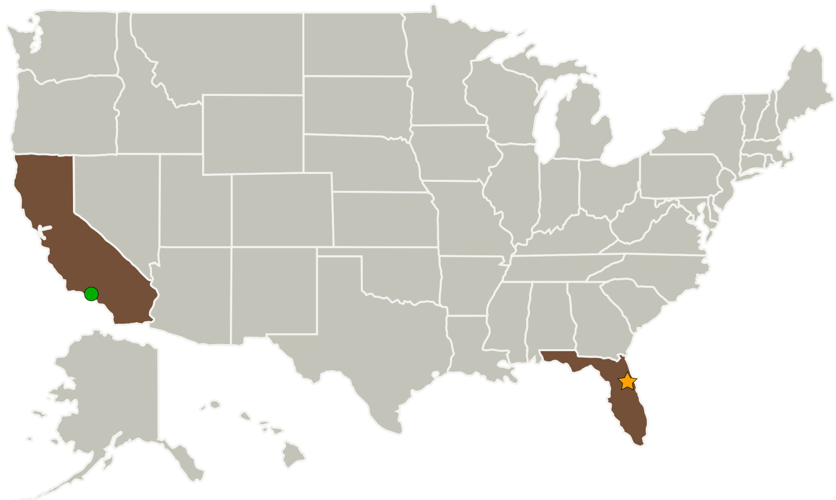


Technology Areas

Primary:

- TX07 Exploration Destination Systems
  └ TX07.2 Mission Infrastructure, Sustainability, and Supportability
    └ TX07.2.2 In-Situ Manufacturing, Maintenance, and Repair

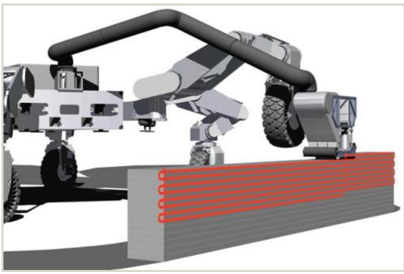
Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Kennedy Space Center(KSC)	Lead Organization	NASA Center	Kennedy Space Center, Florida
●Jet Propulsion Laboratory(JPL)	Supporting Organization	NASA Center	Pasadena, California
QinetiQ North America(QNA)	Supporting Organization	Industry	

Primary U.S. Work Locations	
California	Florida

Images



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(https://techport.nasa.gov/image/2475)